UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
SEATTLE, WASHINGTON

TECHNICAL SUPPORT DOCUMENT
REVIEW OF SHELL'S
AMBIENT AIR QUALITY IMPACT ANALYSIS
FOR THE KULLUK OCS PERMIT APPLICATION
PERMIT NO. R10OCS030000

July 18, 2011

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A. Introduction

This Technical Support Document (TSD) provides the U.S. EPA Region 10's (Region 10's) findings regarding the ambient air quality analysis submitted by Shell Offshore Incorporated (Shell) for the Shell Beaufort Sea Alaska Exploratory Drilling Program using the Kulluk Conical Drilling Unit (Kulluk). Shell submitted this analysis in support of their February 28, 2011 Outer Continental Shelf Permit Application, as revised on May 4, 2011 (Martin 05/04/11), June 22, 2011 (Winges 06/22/11), and July 13, 2011 (Rudy 07/13/11). For the reasons described below, Shell's analysis adequately shows that operating the Kulluk and associated support vessels within the requested constraints will not cause or contribute to violations of the National Ambient Air Quality Standards (NAAQS).

B. Background

Shell is planning to use the Kulluk to conduct exploratory drilling within select lease blocks on the Outer Continental Shelf (OCS) in the Beaufort Sea. Drilling would occur for up to 120 days during each July through November drilling season. The drilling season will likely include both open water and broken ice conditions. The locations and Shell's plan of operation are fully described in Region 10's Statement of Basis (SOB) accompanying the draft permit.

C. Regulatory Overview

The application requirements are fully described in the SOB. In summary, Shell's proposal is subject to the air quality permitting requirements under the OCS provisions of Title 40, Code of Federal Regulations (CFR), Part 55. Under these regulations, the applicable requirements depend on the source's relative location to shore. OCS sources located within 25 miles of a State's seaward boundary are subject to the Federal, and to the State and local requirements of the Corresponding Onshore Area (COA) which have been incorporated into EPA's OCS regulations at 40 CFR Part 55 (Part 55). OCS sources located beyond 25 miles of a State's seaward boundary are subject to only Federal requirements – i.e., COA requirements do not apply. In Shell's case, the State of Alaska is the designated COA and the air quality permitting requirements of the Alaska Department of Environmental Conservation (ADEC) which have been incorporated into 40 CFR Part 55 apply. See 40 CFR § 55.15, Appendix A.

Shell requested that Region 10 impose emission limits to avoid the Prevention of Significant Deterioration (PSD) construction permit requirements for operation on lease blocks that are both within and beyond 25 miles of Alaska's seaward boundary. For operations within 25 miles of Alaska's seaward boundary, Shell submitted a minor permit application pursuant to the COA's minor permit program in Title 18 of the Alaska Administrative Code (AAC), Chapter 50. For operations beyond 25 miles of Alaska's seaward boundary, Shell submitted a Title V operating permit application under 40 CFR Part 71 (Part 71). Shell is also requesting that Region 10 issue a Title V operating permit under the COA regulations for continued operation within 25 miles of the seaward boundary. The ambient demonstration obligations for these various classifications are summarized below in Table 1 and are described in more detail in the following subsections.

Table 1: Ambient Demonstration Obligations by Permit Classification

Permit Classification	Air Pollutant						
	NO_2	SO_2	PM-10	PM-2.5	CO	O_3	Pb
18 AAC 50.502(c)(1)	X		X				
18 AAC 50.502(c)(2)(A)	X	X	X				
Part 70/71 (Title V)	X	X	X	X	X	X	X

C.1 Modeling Obligations under the COA's Minor Permit Program

Shell's request for an Owner Requested Limit (ORL) to avoid PSD classification would trigger the COA rules in ADEC's minor permit requirements in 18 AAC 50.508(5)[1]. Applications classified under this provision are not required to include an ambient air demonstration. However, Shell's proposal would also trigger additional minor permit classifications under the COA regulations, which have air quality demonstration requirements. These additional classifications are:

- 18 AAC 50.502(c)(1)(A) for a new stationary source with a potential to emit greater than 15 tons per year (tpy) of particulate matter with an aerodynamic diameter of less than 10 microns (PM-10);
- 18 AAC 50.502(c)(1)(B) for a new stationary source with a potential to emit greater than 40 tpy of nitrogen oxides (NOx); and
- 18 AAC 50.502(c)(2)(A) for relocating a portable oil and gas operation.

Per 18 AAC 50.540(c)(2)(A), applicants subject to 18 AAC 50.502(c)(1) must show that the proposed potential emissions from the stationary source will not violate the ambient air quality standards established for the triggered pollutants. In Shell's case, they would need to demonstrate compliance with the PM-10 ambient air quality standard and the nitrogen dioxide (NO_2) ambient air quality standard. SO_2 modeling would not be required under this provision, but it would be required under 18 AAC 50.540(c)(2)(B). Under this latter provision, applicants subject to 18 AAC 50.502(c)(2)(A) – i.e., portable oil and gas operations – must demonstrate compliance with the NO_2, PM-10, and SO_2 ambient air quality standards.

The COA rules establish a minor permit threshold and subsequent ambient demonstration requirement for lead (potential emissions that exceed 0.6 tpy) and for carbon monoxide (CO) – if the source emits at least 100 tpy and is located within 10 kilometers (km) of a CO nonattainment area. Shell's proposal does not trigger either of these additional minor permit classifications. Therefore, lead (Pb) and CO modeling would not be required under the COA's minor permit program.

The COA rules do not include minor permit thresholds or ambient demonstration requirements for ozone, particulate matter with an aerodynamic diameter of less than 2.5 microns (PM-2.5), or the two pollutants with state-only ambient air quality standards: ammonia (NH_3) and reduced sulfur compounds. Therefore, minor permit applicants have no regulatory obligation to

[1] References to a particular regulation in the AAC are intended to refer to the versions of the regulations that have been incorporated into Part 55.

demonstrate compliance with the ozone, PM-2.5, NH_3 and reduced sulfur ambient air quality standards. Likewise the rules do not require minor permit applicants to demonstrate compliance with the "maximum allowable increases" (also known as PSD increments), or conduct any type of visibility impact analysis.

Shell provided an ambient demonstration for all pollutants triggered under the COA's minor permit program (NO_2, SO_2 and PM-10). While not required, they also submitted an ambient demonstration for the State of Alaska's NH_3 air quality standard.

C.2 Modeling Obligations under 40 CFR Part 71

As specified in 40 CFR § 55.13(f)(2), the requirements of Part 71 apply to OCS sources located beyond 25 miles of state's seaward boundaries. Since the potential to emit (PTE) for the project is greater than 100 tpy for several criteria pollutants, the Kulluk is classified as a Title V major source under Part 71.

Part 71 includes as "applicable requirements", "any national ambient air quality standard or increment or visibility requirement under part C of Title I of the Clean Air Act (Act), but only as it would apply to temporary sources permitted pursuant to section 504(e) of the Act." 40 CFR § 71.2. As discussed in the SOB, EPA believes the best interpretation of these provisions is that the NAAQS are applicable requirements for all Title V temporary sources, but that increment and visibility are applicable requirements only if such sources would otherwise be subject to PSD.

Part 71 does not specify how a Title V temporary source must demonstrate compliance with the NAAQS. In the absence of regulations or guidance setting out the requirements for a demonstration that the terms and conditions of a Title V permit for a Title V temporary source will assure compliance with NAAQS at all authorized locations of operation, Region 10 believes that following the regulations and guidance for conducting an air quality analysis with respect to the NAAQS under the PSD program is an appropriate approach. See 40 CFR Part 51, Appendix W.

The modeling analysis Shell submitted under the minor permit is consistent with PSD modeling requirements. Therefore, Shell's minor permit analysis meets the PSD NAAQS demonstration requirements for the pollutants triggered under the minor permit program. For the CO and PM-2.5 NAAQS, Shell submitted ambient demonstrations following the PSD demonstration requirements. Shell did not provide a modeling analysis for the Pb and ozone NAAQS.

Shell's decision to not provide a modeling analysis for Pb and ozone NAAQS is reasonable and supportable. It is reasonable because diesel-fired combustion units do not typically release substantive quantities of Pb and ozone-precursor emissions (volatile organic compounds or VOCs), and diesel fuel tanks do not emit large quantities of VOCs. Also, ensuring emissions of other pollutants, especially NO_2 and PM-2.5, do not cause or contribute to a violation of the NAAQS will provide similar assurance for Pb and ozone-precursor emissions for this type of source. Shell's decision is supportable because Pb and VOC emissions are below PSD significant emission rates for both pollutants. Shell's quantitative demonstration that they are complying with the NO_2 and PM-2.5 NAAQS is therefore sufficient for qualitatively demonstrating compliance with the Pb and ozone NAAQS. Additional information regarding ozone may be found in Section H of this TSD.

C.3 Modeling Obligations under 40 CFR Part 70

Shell's request for a Title V permit for continued operation within 25 miles of the seaward boundary did not trigger any ambient demonstration obligations not already triggered under the COA's minor permit program or Part 71.

C.4 Additional Discussion of Regulatory Obligations

For simplicity purposes, Region 10 intends to issue a single OCS permit that fulfills all three permitting mechanisms. This TSD therefore addresses Region 10's review of all ambient demonstration obligations, without further reference to the specific permit mechanism (e.g., COA minor permit program vs. Title V permit obligations).

D. Modeling Approach

A dispersion model is a computer simulation that uses mathematical equations to predict air pollution concentrations based on weather, topography, source characteristics and emissions data. Each of these aspects must be represented with numerical values that characterize the given features of the particular application and location.

Region 10 evaluated Shell's modeling analysis under the guidance established in 40 CFR Part 51, Appendix W, *Guideline on Air Quality Models* (Appendix W). The use of Appendix W for modeling analysis is required under the minor permit program, per 18 AAC 50.215(b). As discussed above, Region 10 believes it is appropriate to use Appendix W for assessing criteria pollutant modeling assessments required under Title V for Title V temporary sources. 40 CFR Part 51, Appendix W, Section 1.0(a).

D.1 Air Quality Model

As stated in Section 3.1 of Appendix W, EPA has developed models suitable for regulatory application. When a single model is found to perform better than others, it is recommended for application as a preferred model and listed in Appendix A of Appendix W. Shell employed the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) system of programs to estimate their ambient impacts (EPA 2002).

Shell and Region10 started discussing refined modeling options for the Arctic marine environment in June 2010. The initial discussion focused on two preferred models for near-field applications: (1) the Offshore and Coastal Dispersion (OCD) model (DiCristofaro et al. 1989) and AERMOD, and (2) a non-guideline over water version of CALPUFF (BOEMRE 2006). Shell and Region 10 ultimately selected AERMOD after examining the capabilities of each model (EPA 04/01/11).

The AERMOD Modeling System consists of three basic modules: AERMAP (which is used to process terrain data and develop elevations for the receptor grid/sources), AERMET (which is used to process the meteorological data), and the AERMOD dispersion model (which is used to estimate the ambient concentrations). There are also several additional components used to process data or develop the parameters needed by these modules.

Shell used the version of AERMOD that was current when the Kulluk application was submitted on February 28, 2011 (version 09292). EPA has subsequently released two updates to AERMOD (version 11059 and version 11103), but these updates do not alter the validity of Shell's analysis. EPA released AERMOD version 11059 to correct several errors associated with use of the "Volume" source option – which was not used by Shell – and to introduce new features to better format the results for comparison to the 1-hour NO_2/SO_2 standards and the PM-2.5 standards. While these new features would have been "handy" to have for the Shell analysis, the lack of these features do not in any way detract from the accuracy of Shell's analysis. EPA released AERMOD version 11103 to correct an error in certain applications of the features introduced in version 11059, and to introduce additional internal checks for certain types of data files. None of these changes call into question the validity of Shell's analysis.

Shell used AERMET to process the meteorological data during periods of broken ice, and a non-Guideline model, the Coupled Ocean-Atmosphere Response Experiment (COARE) bulk flux algorithm (Fairall et al. 2003), to process the meteorological data during open water conditions. The meteorological data used to run AERMOD, along with Shell's approach for processing the meteorological data, is discussed in more detail in Section E of this TSD. Shell did not need to use AERMAP for this analysis since the Beaufort Sea is assumed to be flat.

D.2 Urban/Rural Area Determination

Shell did not utilize the AERMOD option to incorporate the effects of increased surface heating from an urban area. Shell's approach is appropriate since there are no urban areas in the Beaufort Sea.

D.3 Operating Scenarios

Shell's proposed project consists of positioning the Kulluk within one of the lease blocks, setting anchors to stabilize the vessel, and drilling into the seafloor. A support fleet will patrol at a distance to break ice, transfer supplies and personnel, and provide assistance in case of any oil spillage.

D.3.1 General Discussion

According to Shell, the drilling of an exploratory well can take up to 30 days. The drilling process consists of the following three activities: 1) drilling of the "mud-line cellar" (MLC), 2) drilling of the well, and 3) casing, logging, and cementing. With a 30-day drilling cycle, Shell could theoretically complete up to four exploratory wells within a 120 day period.

The relative location of each well is currently unknown. Part of the decision regarding the location for subsequent wells will depend on what Shell learns from a previous drilling. The relative locations could be close enough for the project to have overlapping impacts on an annual average basis. Shell accounted for this potential overlap of plumes by assuming all four wells are drilled at the same location. This is a conservative assumption since it maximizes the effects of plume overlap. In reality, the drilling of four wells at the same location, and the corresponding overlap of plumes, would not occur.

Shell commits to operate the Kulluk incinerator for no more than 12 hours per day, and the emergency generator for no more than two hours per every 30 days. For modeling purposes, Shell assumed the incinerator operates between 8 a.m. and 8 p.m. They assumed the emergency generator operates for only two hours once every 30 days, but the two hours were assumed to occur during the worst-case emissions – the MLC phase of operation.

D.3.2 Associated Fleet

Vessels servicing or associated with an OCS source are included in the source's "potential to emit" (PTE) calculations when operating within 25 miles of the source. 40 CFR § 55.2. Shell therefore included the service vessels, or associated fleet, in their ambient analysis. The associated fleet consists of a primary ice management vessel, a secondary ice management vessel – which also serves as the anchor handler – one oil spill response (OSR) vessel, four oil spill work boats, and resupply vessels/barges.

The resupply vessel(s) will move in and out of the 25-mile radius as needed. Transit takes approximately 4-hours. When loading/off-loading the Kulluk, the resupply vessel will operate in "dynamic positioning" (DP) mode, which means that it will maintain position with its propulsion engines.[2] For its modeling analysis, Shell assumed resupply would occur once every five days, and that each DP mode would last 24-hours. Shell did not include the transit mode in the modeling analysis since that would not occur concurrently with the DP mode and the DP mode provides the worst-case scenario (on both an emission rate and length of operation basis).

Shell assumed the ice management vessels are operating at their maximum rate during the broken ice periods (i.e., the "AERMET" periods). During the open water ("COARE") periods, Shell initially assumed that the ice management vessels are beyond the 25-mile radius. Region 10 questioned this assumption since the application also indicated that Shell wanted to use the "secondary" ice management vessel as an anchor handler during the open water periods. Shell therefore revised their analysis by assuming that both ice management vessels are operating at maximum load during the open water periods (Ruddy 07/13/11). This is a conservative approach since Shell does not intend to operate the primary ice management vessel within the 25-mile radius during open water periods, plus there should not be a need to operate the anchor handler under full load conditions during this period. The revised impacts are only marginally larger than what Shell previously found.

D.3.3 Scenario Management

Shell incorporated the 120-day limit in their modeling of NO_2, SO_2, PM-10 and PM-2.5 impacts. To ensure the modeled results were not underestimated by their selection of when the 120-day period would occur, Shell modeled two 120-day periods: an "early season" period (July 1 through October 28th); and a "late-season" (August 3rd through November 30th). Shell then took the higher of the two impacts for comparison to the air quality standards.

[2] Shell noted that the resupply vessel could be a tug and barge. In this case, the barge – which has no emissions – would be moored to the Kulluk during loading/off-loading, and the tug would only be present to move the barge in and out of the 25-mile radius. However, these emissions would be less than the resupply vessel in DP mode – which was modeled as a worst-case scenario.

Shell also incorporated the various levels of operation during a 30-day drilling sequence in their NO_2, SO_2, PM-10, and PM-2.5 analysis. They did this by creating an AERMOD input file for each hour of the 120-day period (2,880 files) for each pollutant. They then ran AERMOD for each file and post-processed the results.

Shell used the full five month (153-day) meteorological period when modeling their CO and NH_3 impacts. They also used the worst-case emissions for each unit and assumed all units are operating concurrently. This is a conservative and therefore acceptable approach.

Shell prorated the period averages in order to estimate the annual average impacts. For example, to estimate the annual average NO_2, PM-2.5, or SO_2 impacts, Shell multiplied the 120-day average impact by 0.329 (120 drilling days out of 365 days in a year). Shell's approach for estimating the annual average impact is reasonable since the impact during non-drilling periods will be zero.

D.4 Emission Unit Inventory and Location

Shell included all of the combustion-related emission units listed in their OCS minor/Title V permit applications in their modeling analysis. The list of modeled emission units is repeated below in Table 2 for convenience purposes. Table 2 also provides the assumed rating and shows whether Shell characterized the emission unit as a point source or as an area source. It also provides the tag that Shell used to identify each emission unit in the modeling files.

There are a number of different vessels that Shell could use to meet their various support needs. Shell treated the associated fleet as generic vessels in order to maintain operational flexibility.

Shell characterized the resupply vessel in DP mode as a point source since it will maintain its position relative to the Kulluk during the loading/off-loading process. Shell characterized all other vessels as area sources, since their duties require transient operation. The relative location of the vessels is shown in Figure 1 and described in Section 3.3.3 of their application. In summary, Shell assumed the ice management vessels would operate throughout a pie-shaped area upwind of the Kulluk, and the OSR vessels would operate throughout a 2 km by 2 km area downwind of the Kulluk. The ice management "pie" was 5 km long and 40-degrees wide. Since Shell used hourly input files for their NO_2, SO_2, PM-10, and PM-2.5 analysis, they were able to change the cardinal coordinates of these area sources on an hourly basis, in order to keep the area sources in-line with the wind direction. For the CO and NH_3 analysis, Shell aligned the area sources in the predominate upwind/downwind direction and held them in this same position for the entire 153-day period.

Varying the orientation of the associated fleet with the prevailing wind direction provides a conservative impact analysis as all the emissions are aligned such that the highest cumulative impacts from all equipment will occur. This also best reflects how the actual drilling operations are performed.

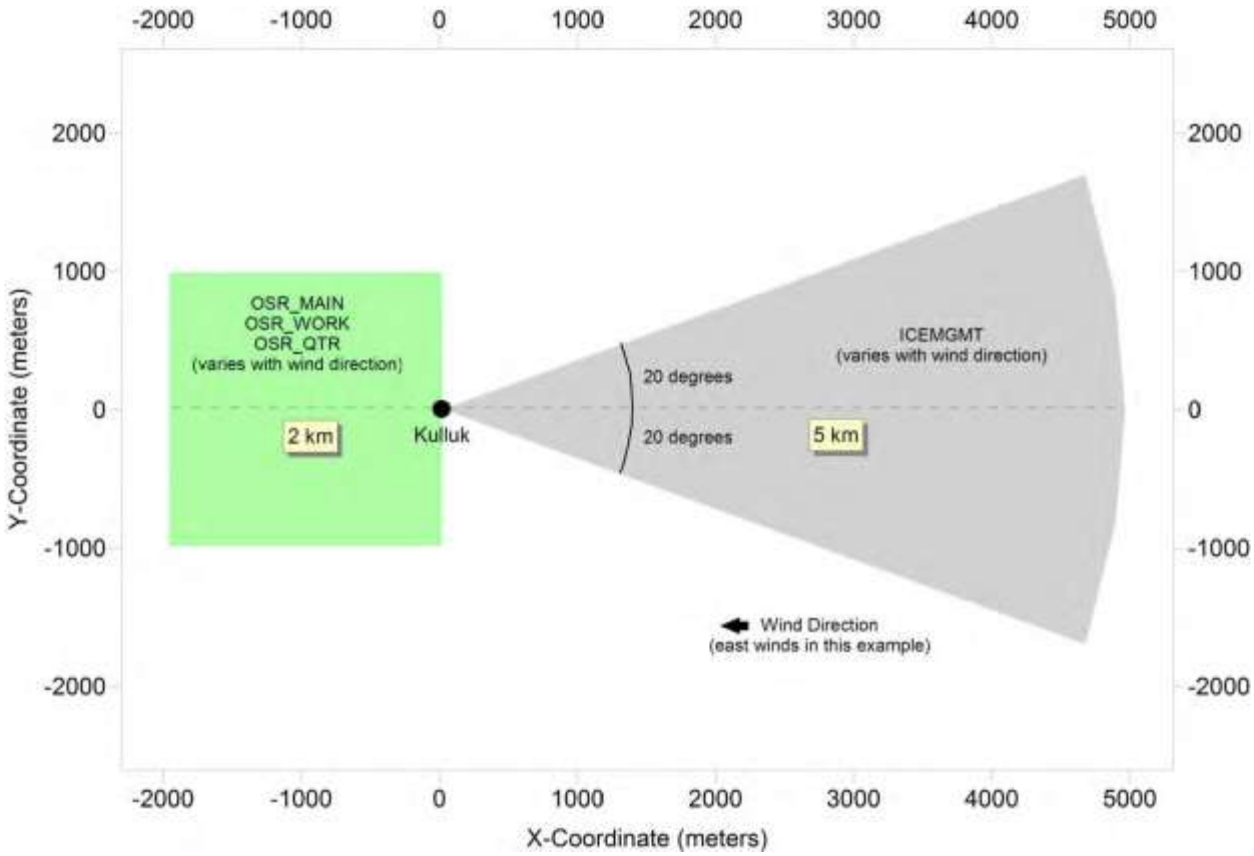
Shell used a local Cartesian coordinate system for designating all emission unit locations. They used the drill hole as the origin (0, 0 point) of their coordinate system.

Table 2: Emission Unit Location

Emission Unit			Source	Location	
Description	Model ID	Rated Capacity	Type	x (m)	y (m)
Kulluk [a]					
Generators	MAINENGS	8,500 hp [b]	Point	-38.2	2.8
MLC Hydraulic Power Unit (HPU)	MLCHPU_A	750 hp	Point	11.0	36.4
MLC Hydraulic Power Unit (HPU)	MLCHPU_B	750 hp	Point	11.0	36.4
Air Compressor (port)	AIRCMP_A	750 hp	Point	-36.8	12.0
Air Compressor (starboard)	AIRCMP_B	750 hp	Point	25.1	-32.2
Crane	CRANE_A	400 hp	Point	-28.3	28.3
Crane	CRANE_B	400 hp	Point	30.1	27.9
Crane	CRANE_C	400 hp	Point	29.7	-29.7
Heaters & Boilers	HEATBOIL	6 MMBtu/hr	Point	-38.5	-5.3
Incinerator	INCIN_K	276 lb/hr	Point	11.7	-32.9
Seldom Used Units (typical operations)	SELDOML	0.79 gal/hr	Point	-2.1	38.9
Seldom Used Units (Em. Gen. – exercising)	SELDOMH	38.5 gal/hr	Point	-2.1	38.9
Associated Fleet [c]					
Resupply Ship (DP Mode)	RESUP_DP	12,000 hp	Point	87.7	81.5
Ice Management/Anchor Handler [d]	ICEMGMT	64,400 hp	Areapoly	Varies Hourly	
Main OSR Ship	OSR_MAIN	3,487 hp	Areapoly	Varies Hourly	
OSR Work Boats	OSR_WORK	23 gal/hr	Areapoly	Varies Hourly	

a. Kulluk emission units. Shell used a single location for the generator engines and the HPU engines. This approach makes for a conservative analysis since it overlaps the impacts.
b. Shell subsequently noted that they may replace the existing generator sets with new generator sets that have a total rated capacity of 10,400 hp. The modeled emission limits would still apply. This change does not alter the conclusions made in this TSD.
c. The rated capacity for the associated fleet is the total propulsion and generation capacity. The support vessels may also have miscellaneous heaters, small incinerators, and seldom used engines.
d. The 64,400 hp capacity for the Ice Management/Anchor Handler is the *total* propulsion/generation capacity between two generic 32,200 hp vessels.

Figure 1: Relative Location of the Associated Fleet for Modeling Purposes



D.5 Modeled Emission Rates

As previously discussed, Shell incorporated the various levels of operation during a 30-day drilling sequence in their NO_2, SO_2, PM-10 and PM-2.5 analysis. Therefore, the modeled emission rate varied on an hourly/daily basis for these pollutants. For example, Shell assumed the Kulluk HPU and air compressor emission units are emitting during the five days of MLC operation, but not during the remaining 25 days of the drilling sequence.

When the units are operating, Shell used the same basic emission rates as used in their permit applicability analysis (i.e., the emission units have the same level of operation and post-combustion controls as described in Attachment A of their permit application). The NO_2, SO_2, PM-10, and PM-2.5 gram per second (g/s) emission rates used by Shell in the modeling analysis are provided below in Table 3 through Table 5, for each modeled emission unit.[3] Table 3 provides the modeled emission rates during the MLC phase. Table 4 provides the rates during the drilling phase. Table 5 provides the rates during the cementing/logging phase. The equivalent pound per hour (lb/hr) value for each unit/pollutant is also provided in each of these

[3] Emissions for an area source are actually entered into AERMOD as a gram per second per square meter value (i.e., the g/s emission rated divided by the source area). Region 10 converted the modeled $g/s/m^2$ values into g/s values, in order to provide a consistent format.

tables. Shell used the maximum CO and NH_3 emission rate from any of the three scenarios in their CO and NH_3 analysis. The maximum g/s and lb/hr CO and NH_3 emission rates are provided in Table 6.

Shell stated that the seldom used units have highly intermittent use, but need to be exercised on an infrequent scheduled cycle. With one exception, Shell estimated the expected weekly/monthly fuel consumption for these intermittent units and then used the equivalent hourly fuel consumption to estimate the g/s emission rates needed for modeling purposes. Shell then assumed these seldom used units are constantly operating at this emission rate. The exception pertains to the Kulluk emergency generator, which is substantially larger than the other seldom used units. With respect to 1-hour NO_2, the use of maximum allowable emissions for intermittent emergency generators may result in modeled impacts that are substantially higher than realistic impacts (EPA 3/01/11). The guidance provides that in certain circumstances it may be appropriate to exclude emergency generators from compliance demonstrations. In this case, Shell included the emergency generator with the assumption that it would operate for only 2 hours during the 30-day cycle. Shell further assumed the emissions would occur during the MLC phase (which has the largest emissions of the three phases), in order to provide a worst-case analysis. Shell's approach for characterizing the various intermittent emission units is reasonable and in the emergency generator case, conservative, since they could have excluded the emergency generator from the 1-hour NO_2 analysis.

Table 3: Modeled Emission Rates – MLC Phase

Emission Unit		NOx		PM-2.5		PM-10		SO_2	
Description	Model ID	g/s	lb/hr	g/s	lb/hr	g/s	lb/hr	g/s	lb/hr
Generators	MAINENGS	2.395	19.0	0.374	2.97	0.374	2.97	6.80E-02	0.54
MLC HPU	MLCHPU_A	2.330	18.5	0.093	0.74	0.093	0.74	7.06E-03	5.6E-02
MLC HPU	MLCHPU_B	2.330	18.5	0.093	0.74	0.093	0.74	7.06E-03	5.6E-02
Air Comp (port)	AIRCMP_A	1.864	14.8	0.039	0.31	0.039	0.31	7.06E-03	5.6E-02
Air Comp (starboard)	AIRCMP_B	1.864	14.8	0.039	0.31	0.039	0.31	7.06E-03	5.6E-02
Crane	CRANE_A	0.149	1.18	0.006	0.05	0.006	0.05	4.52E-04	3.6E-03
Crane	CRANE_B	0.149	1.18	0.006	0.05	0.006	0.05	4.52E-04	3.6E-03
Crane	CRANE_C	0.149	1.18	0.006	0.05	0.006	0.05	4.52E-04	3.6E-03
Heaters & Boilers	HEATBOIL	0.115	0.91	0.019	0.15	0.019	0.15	8.06E-03	6.4E-02
Incinerator	INCIN_K	0.052	0.41	0.243	1.93	0.285	2.26	0.04	0.32
Seldom (no gen)	SELDOML	0.046	0.37	0.004	0.03	0.004	0.03	1.39E-04	1.1E-03
Seldom (Em. Gen)	SELDOMH	2.242	17.8	0.179	1.42	0.179	1.42	6.79E-03	5.4E-02
Resupply Ship (DP Mode)	RESUP_DP	9.32	74.0	0.39	3.10	0.39	3.10	0.04	0.32
Ice Management	ICEMGMT	21.88	174	3.68	29.2	3.72	29.6	0.68	5.41
OSR Vessel	OSR_MAIN	5.476	43.5	0.339	2.69	0.358	2.84	0.040	0.32
OSR Work Boats	OSR_WORK	1.313	10.4	0.105	0.83	0.105	0.83	3.98E-03	3.2E-02

Table 4: Modeled Emission Rates – Drilling Phase

Emission Unit		NOx		PM-2.5		PM-10		SO_2	
Description	Model ID	g/s	lb/hr	g/s	lb/hr	g/s	lb/hr	g/s	lb/hr
Generators	MAINENGS	2.395	19.0	0.374	2.97	0.374	2.97	6.80E-02	0.54
MLC HPU	MLCHPU_A	0	0	0	0	0	0	0	0
MLC HPU	MLCHPU_B	0	0	0	0	0	0	0	0
Air Comp (port)	AIRCMP_A	0	0	0	0	0	0	0	0
Air Comp (starboard)	AIRCMP_B	0	0	0	0	0	0	0	0
Crane	CRANE_A	0.149	1.18	0.006	0.05	0.006	0.05	4.52E-04	3.6E-03
Crane	CRANE_B	0.149	1.18	0.006	0.05	0.006	0.05	4.52E-04	3.6E-03
Crane	CRANE_C	0.149	1.18	0.006	0.05	0.006	0.05	4.52E-04	3.6E-03
Heaters & Boilers	HEATBOIL	0.115	0.91	0.019	0.15	0.019	0.15	8.06E-03	6.4E-02
Incinerator	INCIN_K	0.052	0.41	0.243	1.93	0.285	2.26	0.04	0.32
Seldom (no gen)	SELDOML	0.046	0.37	0.004	0.03	0.004	0.03	1.39E-04	1.1E-03
Seldom (Em. Gen)	SELDOMH	2.242	17.8	0.179	1.42	0.179	1.42	6.79E-03	5.4E-02
Resupply Ship (DP Mode)	RESUP_DP	9.32	74.0	0.39	3.10	0.39	3.10	0.04	0.32
Ice Management	ICEMGMT	21.88	174	3.68	29.2	3.72	29.6	0.68	5.41
OSR Vessel	OSR_MAIN	5.476	43.5	0.339	2.69	0.358	2.84	0.040	0.32
OSR Work Boats	OSR_WORK	1.313	10.4	0.105	0.83	0.105	0.83	3.98E-03	3.2E-02

Table 5: Modeled Emission Rates – Cementing/Logging Phase

Emission Unit		NOx		PM-2.5		PM-10		SO_2	
Description	**Model ID**	**g/s**	**lb/hr**	**g/s**	**lb/hr**	**g/s**	**lb/hr**	**g/s**	**lb/hr**
Generators	MAINENGS	1.690	13.4	0.264	2.10	0.264	2.10	4.80E-02	0.38
MLC HPU	MLCHPU_A	0	0	0	0	0	0	0	0
MLC HPU	MLCHPU_B	0	0	0	0	0	0	0	0
Air Comp (port)	AIRCMP_A	0	0	0	0	0	0	0	0
Air Comp (starboard)	AIRCMP_B	0	0	0	0	0	0	0	0
Crane	CRANE_A	0.249	1.98	0.010	0.08	0.010	0.08	7.53E-04	6.06E-03
Crane	CRANE_B	0.249	1.98	0.010	0.08	0.010	0.08	7.53E-04	6.06E-03
Crane	CRANE_C	0.249	1.98	0.010	0.08	0.010	0.08	7.53E-04	6.06E-03
Heaters & Boilers	HEATBOIL	0.115	0.91	0.019	0.15	0.019	0.15	8.06E-03	6.4E-02
Incinerator	INCIN_K	0.052	0.41	0.243	1.93	0.285	2.26	0.04	0.32
Seldom (no gen)	SELDOML	0.046	0.37	0.004	0.03	0.004	0.03	1.39E-04	1.1E-03
Seldom (Em. Gen)	SELDOMH	2.242	17.8	0.179	1.42	0.179	1.42	6.79E-03	5.4E-02
Resupply Ship (DP Mode)	RESUP_DP	9.32	74.0	0.39	3.10	0.39	3.10	0.04	0.32
Ice Management	ICEMGMT	21.88	174	3.68	29.2	3.72	29.6	0.68	5.41
OSR Vessel	OSR_MAIN	5.476	43.5	0.339	2.69	0.358	2.84	0.040	0.32
OSR Work Boats	OSR_WORK	1.313	10.4	0.105	0.83	0.105	0.83	3.98E-03	3.2E-02

Table 6: Modeled CO and NH_3 Emission Rates

Emission Unit		CO		NH_3	
Description	**Model ID**	**g/s**	**lb/hr**	**g/s**	**lb/hr**
Generators	MAINENGS	1.08	8.6	0.09	0.71
MLC HPU	MLCHPU_A	0.13	1.0	0	0
MLC HPU	MLCHPU_B	0.13	1.0	0	0
Air Comp (port)	AIRCMP_A	0.11	0.9	0	0
Air Comp (starboard)	AIRCMP_B	0.11	0.9	0	0
Crane	CRANE_A	0.01	0.1	0	0
Crane	CRANE_B	0.01	0.1	0	0
Crane	CRANE_C	0.01	0.1	0	0
Heaters & Boilers	HEATBOIL	0.03	0.2	0	0
Incinerator	INCIN_K	5.22	41.4	0	0
Seldom (no gen)	SELDOML	0.012	0.1	0	0
Seldom (Em. Gen)	SELDOMH	0.605	4.8	0	0
Resupply Ship (DP Mode)	RESUP_DP	2.81	22.3	0	0
Ice Management	ICEMGMT	15.61	123.9	0.40	0.79
OSR Vessel	OSR_MAIN	4.00	31.7	0	0
OSR Work Boats	OSR_WORK	0.35	2.8	0	0

D.6 Emission Unit Characterization

In addition to providing the model with an emission rate, the release characteristics must be provided in order for the model to estimate how the release disperses over time. The release parameters needed for modeling point sources include stack height, stack gas exit temperature, stack gas exit velocity and inside stack diameter. Modeling polynomial area sources with buoyant exhaust characteristics requires a description of the polynomial (i.e, the corner coordinates), the release height and the initial vertical spread of the exhaust plume (sigma-z). The unit-specific values used by Shell for the point source parameters are listed in Table 3-4 of their application and are repeated in Table 7 for convenience. The values used by Shell are reasonable.

As noted in Section D.4, Shell may replace the existing generator sets with new units. This may lead to some variation in the stack parameters, but not to a degree that calls into question the validity of their analysis. Shell assumed the main generator stacks are collocated, which added a larger degree of conservatism in the modeled impacts than what little change may occur due to small variations in stack parameters.

The presence of non-vertical stacks or stacks with rain caps requires special handling in an AERMOD analysis. Shell assumed all of the point sources (see Table 7) have vertical stacks without rain caps. According to Shell, they are currently modifying the existing Kulluk generator stacks in order to comply with this modeling assumption (Martin 03/28/11).

Shell noted that the resupply vessel is currently unspecified, and could also vary on a year-to-year basis. They also correctly noted that the largest sources do not always produce the largest ambient impacts. The relatively poor dispersion that occurs from smaller sources with their shorter stacks and smaller exhaust flow rates can produce the maximum ambient impacts. Shell therefore conducted a sensitivity analysis of the largest expected resupply vessel (the 6,140 hp Harvey Spirit) and the smallest expected resupply vessel (the 1,700 hp Arctic Seal). Shell found that the Harvey Spirit produces the larger 1-hour NO_2 and 24-hour PM-2.5 impacts, by substantive margins. This same trend would also be expected for the other pollutants and averaging periods. Shell therefore used the Harvey Spirit parameters to develop the “generic” resupply vessel in their modeling analysis. Region 10 concurs with their approach and conclusion.

Table 7: Point Source Stack Parameters

Emission Unit		Release Height Above				
Description	Model ID	Main Deck (m)	Water (m)	Exhaust Temp (K)	Exit Velocity (m/s)	Stack Diameter (m)
Generators	MAINENGS	6.40	13.72	606	30.5	0.60
MLC HPU	MLCHPU_A	3.05	10.36	700	40.0	0.18
MLC HPU	MLCHPU_B	3.05	10.36	700	40.0	0.18
Air Comp (port)	AIRCMP_A	3.66	10.97	606	30.5	0.60
Air Comp (starboard)	AIRCMP_B	4.69	12.01	606	30.5	0.60
Crane	CRANE_A	16.99	24.31	672	20.1	0.25
Crane	CRANE_B	16.99	24.31	672	20.1	0.25
Crane	CRANE_C	16.99	24.31	672	20.1	0.25
Heaters & Boilers	HEATBOIL	6.4	13.72	366	16.1	0.15
Incinerator	INCIN_K	8.81	16.12	623	10.0	0.46
Seldom Used (typical ops)	SELDOML	5.76	13.08	700	40.0	0.18
Seldom Used (Em. Gen)	SELDOMH	5.76	13.08	700	40.0	0.18
Resupply Ship (DP Mode)	RESUP_DP	--	18.29	650	14.6	0.60

Shell conducted preliminary runs of the ice management/anchor handling fleet in order to determine the hourly plume heights and sigma z values as a function of the hourly meteorological conditions. Shell used this variable plume height/sigma z approach for their NO_2, SO_2, PM-10, and PM-2.5 analysis. They used a more conservative approach of just using the lowest predicted plume height and smallest sigma z in their CO and NH_3 analysis.

To do these calculations, Shell performed the preliminary run with a line of receptors along the centerline of the areapoly used for the ice management vessels and determined the worst case concentration at each receptor. Shell then took the corresponding plume heights and vertical dispersion coefficients for the receptor with the highest modeled concentrations. These plume heights and vertical dispersion coefficients then became the final modeled inputs for the ice management vessels in the full impact analysis. A similar approach was used to characterize the oil spill response fleet. The end result of this approach allows Shell to place emissions for the moving associated fleet in the area they generally work while providing a conservative impact analysis by using worst case dispersion characteristics for the portion of the associated fleet that is modeled as an areapoly. Region 10 reviewed this approach and believes it provides a conservative estimate of modeled impacts while adequately characterizing a moving fleet of vessels.

D.7 NO_2 Modeling Technique

The NOx emissions created during combustion are partly nitric oxide (NO) and partly NO_2. After the combustion gas exits the stack, additional NO_2 can be created due to atmospheric reactions. The modeling of ambient NO_2 concentrations therefore requires ambient data or assumptions regarding the atmospheric conversion of NO to NO_2. Section 5.2.4 of Appendix W describes several approaches that may be considered in modeling annual average NO_2 impacts. These approaches are also generally applicable in modeling 1-hour NO_2 impacts (EPA 06/29/10).

Shell used the Plume Volume Molar Ratio Method (PVMRM) (Hanrahan 1999) to estimate their 1-hour and annual average NO_2 impacts. PVMRM is discussed in Section 5.1.j of Appendix W as a technique that EPA is currently testing to determine its suitability as a refined method. In the mean-time, PVMRM may be considered on a case-by-case basis as a non-regulatory-default option under the "detailed screening method" (Tier 3) provision of Section 5.2.4.d of Appendix W (EPA 06/29/10 and EPA 03/01/11).

PVMRM assumes NO will convert to NO_2 in the presence of O_3, based on the following basic chemical mechanism, known as titration:

$$NO + O_3 \rightarrow NO_2 + O_2 \qquad \text{(Eq. 1)}$$

PVMRM also assumes that the NO_2 already present in the exhaust plume remains as NO_2 in the atmosphere. A user of this technique must therefore know or assume the amount of NO_2 present in the exhaust gas, and the amount of O_3 present in the atmosphere. These data requirements, along with the procedural requirements for using PVMRM, are described in more detail below.

D.7.1 Procedural Requirements

As a non-regulatory-default option, use of this technique requires Regional Office approval. It is also subject to public comment. The Regional Modeling Contact for Region 10 approved Shell's use of PVMRM for the Kulluk analysis on May 8, 2011 (EPA 05/08/11). The public will be invited to comment on the use of PVMRM in the public notice which accompanies the draft Kulluk permit.

D.7.2 In-stack NO_2/NOx Ratio

The assumed NO_2-to-NOx in-stack ratio is a variable that must be set for each emission unit with NOx emissions. Source-specific data should be used when available. When source-specific data is not available, EPA recommends the use of 0.50 as a default in-stack ratio for purposes of modeling 1-hour NO_2 impacts (EPA 03/01/11). This value represents "a reasonable upper bound based on the available in-stack data." EPA has not provided a similar default ratio for purposes of modeling annual average NO_2 impacts.

Shell used the preferred approach of obtaining source-specific data, rather than the 0.5 default. Shell developed average ratios for general types of combustion units and post-combustion control combinations, based on numerous source tests of the existing emission units on the Discoverer Drillship and associated fleet. Reliance on these ratios is a reasonable approach given the similarity in emission units.

D.7.3 Ambient Ozone Data

Shell obtained hourly ozone data for 2009 from Barrow and Prudhoe Bay A Pad. (Data from 2010 was not available at the time they prepared their analysis.) Shell then created an hourly ozone data set for modeling purposes by selecting the maximum reading from either station on an hour-by-hour basis.

Using the maximum of the two sites allows for missing hours at either site. Use of the maximum ozone concentration also leads to increased conversion of NO to NO_2 (during those periods when the ambient NO concentration exceeds the ambient ozone concentration). Shell therefore used a reasonable approach for developing a representative ozone data set for modeling NO_2 concentrations over the Beaufort Sea.

Region 10 reviewed both of these datasets and found they were representative of likely ozone levels in the Beaufort Sea. In general the ozone readings at both sites were similar, varying only a few parts per billion (ppb) on an hourly basis. Hourly readings at Barrow were slightly higher on average than those at A pad.

D.8 PM-2.5 Modeling Technique

PM-2.5 is either directly emitted from a source (primary emissions) or formed through chemical reactions with pollutants already in the atmosphere (secondary formation). EPA promulgated AERMOD as an acceptable model for performing near-field analysis of primary pollutants (Appendix A to Appendix W of 40 CFR Part 51 – Summaries of Preferred Air Quality Models, Part A-1). EPA has not developed and recommended, however, a near-field model that includes the necessary chemistry algorithms to estimate secondary impacts in an ambient air analysis.

To address this lack of a comprehensive, near-field modeling tool, EPA issued modeling guidance in 2010 to give further direction on how to conduct an ambient impact analyses for PM-2.5 (EPA 02/26/10 and EPA 03/23/10). This guidance provides that, with appropriate selection of representative background ambient monitoring data, much of the PM-2.5 secondary formation from background sources should be adequately accounted for in most cases, but that in the case of a source that emits significant quantities of PM-2.5 precursor emissions, some assessment of their potential contribution to cumulative impacts as secondary PM-2.5 may be necessary. This assessment could include using other models for the secondary component, such as a photochemical model.

Shell used PM-2.5 ambient monitoring data from an onshore location (Deadhorse) that includes the impacts of secondary PM-2.5 from existing onshore sources. This onshore monitor is expected to have accounted for much of the secondary formation that will occur in the area (i.e. the monitor is exposed to secondary formation from existing regional emissions sources). Shell took the resulting 24-hour monitored background value and added the two-year average of the maximum 24-hour modeled concentration (unpaired in time) to determine the total 24-hour PM-2.5 impact. This approach is consistent with the “First Tier” approach described in the March 23, 2010 PM-2.5 Guidance Memo and is considered conservative. Results of this approach indicate a maximum $PM_{2.5}$ concentration in the Beaufort of 33.9 $\mu g/m^3$ at the assumed ambient air boundary (500 meters from the Kulluk hull) and lower levels as the distance from the Kulluk increases. Additional details regarding the Deadhorse PM-2.5 data may also be found in Section F.3 of this TSD.

It is important to note that secondary formation of PM-2.5 will generally be low near the emission release point (here, the Kulluk), where the modeled concentrations are highest, because there has not been enough time for the secondary chemical reactions to occur. Instead, secondary PM-2.5 impacts will generally occur farther from the emission source. It is therefore unlikely that maximum primary PM-2.5 impacts and maximum secondary PM-2.5 impacts from the Kulluk and the associated fleet will occur at the same time (paired in time) or location (paired in space), providing further assurance that emissions from secondary formation of PM-2.5 will not threaten compliance with the NAAQS. The fact that the PM-2.5 modeling assumed that the Kulluk would be operating in a single drilling location for 3 years, when that scenario is unlikely to occur, further mitigate against the possibility that emissions to be authorized under the permits would cause or contribute to a violation of the NAAQS based on the contribution of PM-2.5 precursor emissions.

Moreover, secondary PM-2.5 formation is a complex photochemical reaction that requires a mix of precursor atmospheric pollutants in sufficient quantities for significant secondary formation to occur. Available PM-2.5 monitoring data from the onshore communities along the Beaufort Sea and in potential transport areas where monitoring is performed, show low levels of PM-2.5, generally in the range of 2 $\mu g/m^3$. The higher PM-2.5 values recorded on monitors in the North Slope generally occur on days where windblown dust or fires are believed to be contributing factors. Thus, there is no indication that secondary formation of PM-2.5 from existing sources in the North Slope is currently causing or contributing to a violation of the PM-2.5 NAAQS in the onshore communities.

The use of Deadhorse ambient monitoring data without additional assessment of the possible secondary PM-2.5 impacts from the Kulluk and associated fleet is therefore appropriate. Emissions of the PM-2.5 precursor SO_2 from the Kulluk and associated fleet are 10 tpy, less than the PM-2.5 Significant Emission Rate (SER) for that precursor. See 40 CFR § 52.21(b)(23)(i). Emissions of the PM-2.5 precursor NOx from the Kulluk and associated fleet are considerably higher, at 240 tpy.[4] As a point of comparison, however, actual emissions of NOx from point sources in the North Slope oil and gas fields within the greater Prudhoe Bay/Deadhorse area are approximately 65,000 tpy, yet the total (not just secondary) PM-2.5 concentrations in Deadhorse are typically quite low. Given the amount of NOx emissions to be authorized under these

[4] Region 10 has not made a determination of whether PM-2.5 precursor emissions from the project are significant, but has instead accounted for the possibility of the formation of secondary PM-2.5 through this non-modeling assessment as provided in the March 23, 2010 PM-2.5 Guidance Memo. Note that EPA’s final regulations for the “Implementation of the New Source Review (NSR) Program for Particulate Matter Less than 2.5 Micrometers (PM-2.5)” (73FR 28321, May 16, 2008), indicate that VOC and NH_3 emissions are presumed not to contribute to secondary formation of PM-2.5.

permits in comparison to the NOx emissions in the North Slope area in general, it is unlikely that NOx emissions from the Kulluk and associated fleet would be expected to cause or contribute to a violation of the PM-2.5 NAAQS given the generally low levels of PM-2.5 recorded at monitoring stations in the area.

In summary, the modeling uses background PM-2.5 monitoring results that are expected to include secondary PM-2.5 formed from existing sources, and PM-2.5 monitoring data throughout the North Slope is generally low except on days where windblown dust or fires are a contributing factor. Region 10 believes that the PM-2.5 NAAQS will be protected at all locations when accounting for secondary precursors from the Kulluk and the associated fleet and that it is not appropriate or necessary to use a photochemical model to further evaluate secondary PM-2.5 formation in this permitting action.

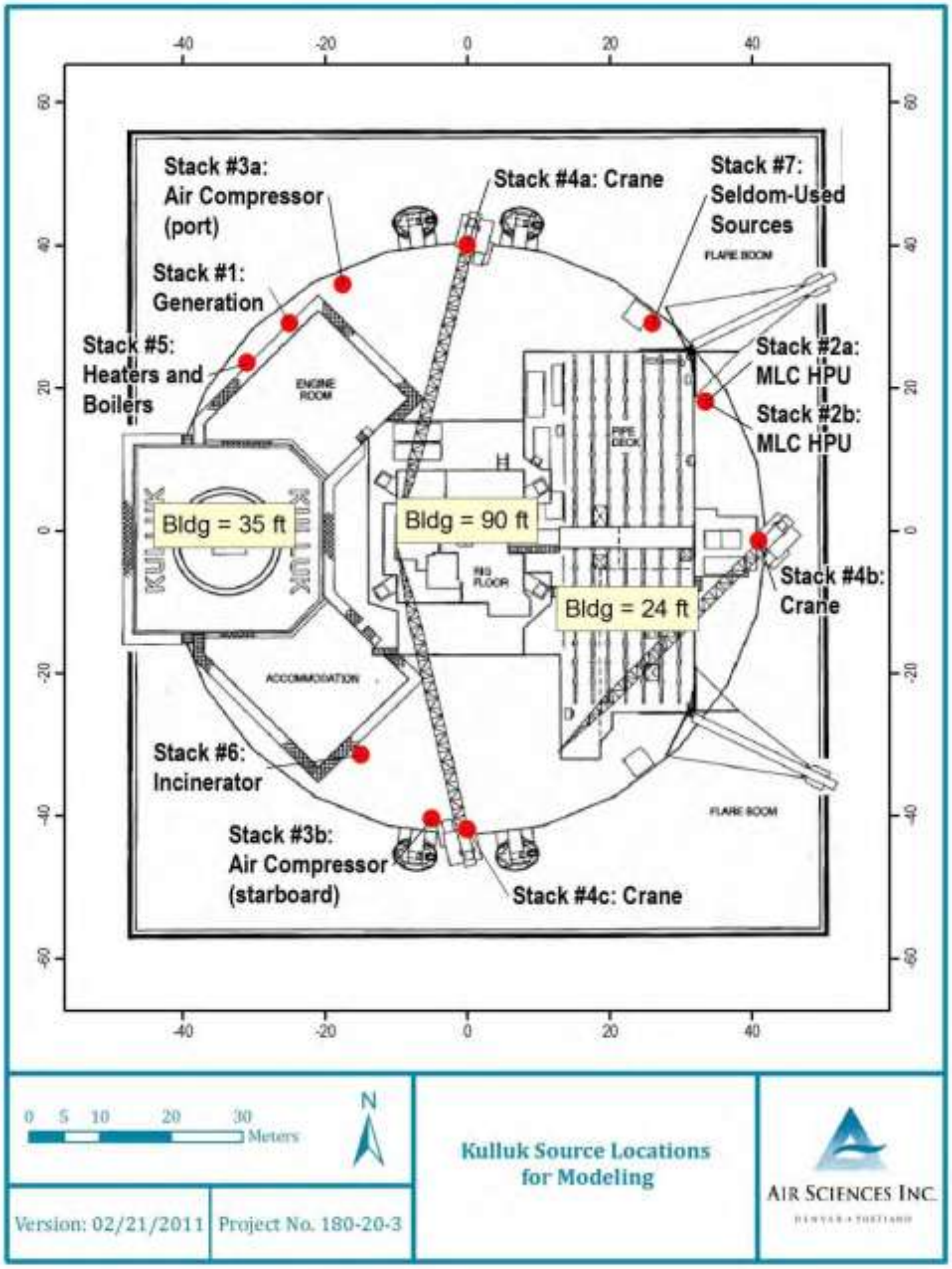
D.9 Building Downwash/Wake Effects

The Building Profile Input Program for PRIME (BPIPPRM) (EPA 4/21/04 User's Guide) calculates direction-specific building dimensions for input into AERMOD. These dimensions are used by the model to account for building downwash and wake effect which result from the effects of airflow around large structures near emission points.

The relative location of the Kulluk exhaust stacks and structures is shown in Figure 2. Shell input the stack location and height for each of the exhaust stacks above the water surface, along with the corner locations and structure height above the water surface of the Kulluk's main deck, the helicopter pad, the pipe deck and the derrick, and the resupply ship's structures into BPIPPRM. Shell used the current version of BPIPPRM – version 04274. Shell included the resulting direction-specific building dimensions in its AERMOD modeling analysis.

Region 10 used a proprietary 3-D visualization program to review Shell's characterization of the exhaust stacks and structure locations/heights. The images generated from Shell's BPIPPRM input file match the photos and figures of the Kulluk, as provided in Shell's permit application.

Figure 2: Kulluk Exhaust Stack and Structure Layout



D.10 Receptor Grid

Shell used the same local Cartesian coordinate system described in Section D.4 to define their modeling domain and receptor grid. Surface elevations were set to 0.0 meters to reflect the lack of terrain in an overwater setting. The grid does not have a defined origin because drilling will occur at multiple locations within the specified permitted lease blocks. Shell's modeling analysis assumed an ambient air boundary of 540 meters from the center of the Kulluk (500m from the hull) which is reflected in its receptor grid.

Figure 3 shows the receptor layout used in the modeling analysis. Shell used a 25 meter (m) spacing around the assumed ambient air boundary. Shell constructed the rest of the grid as follows:

- 100-m spacing out to 1 km from the center of the Kulluk;
- 250-m spacing from 1 km to 5 km from the center of the Kulluk.

Shell's grid has sufficient density and coverage for finding the maximum impacts.

Shell also included three "special interest" receptors to estimate the impacts in Nuiqsut, Deadhorse and Kaktovik. Shell placed these receptors in the same relative direction and distance as what would occur if Shell operated the Kulluk within the nearest corner of the nearest lease block to a given community. The location of these communities relative to Shell's lease blocks in shown in Figure 4.

Figure 3: Modeling Domain and Receptor Points

(The + in the figure represents the *Kulluk*)

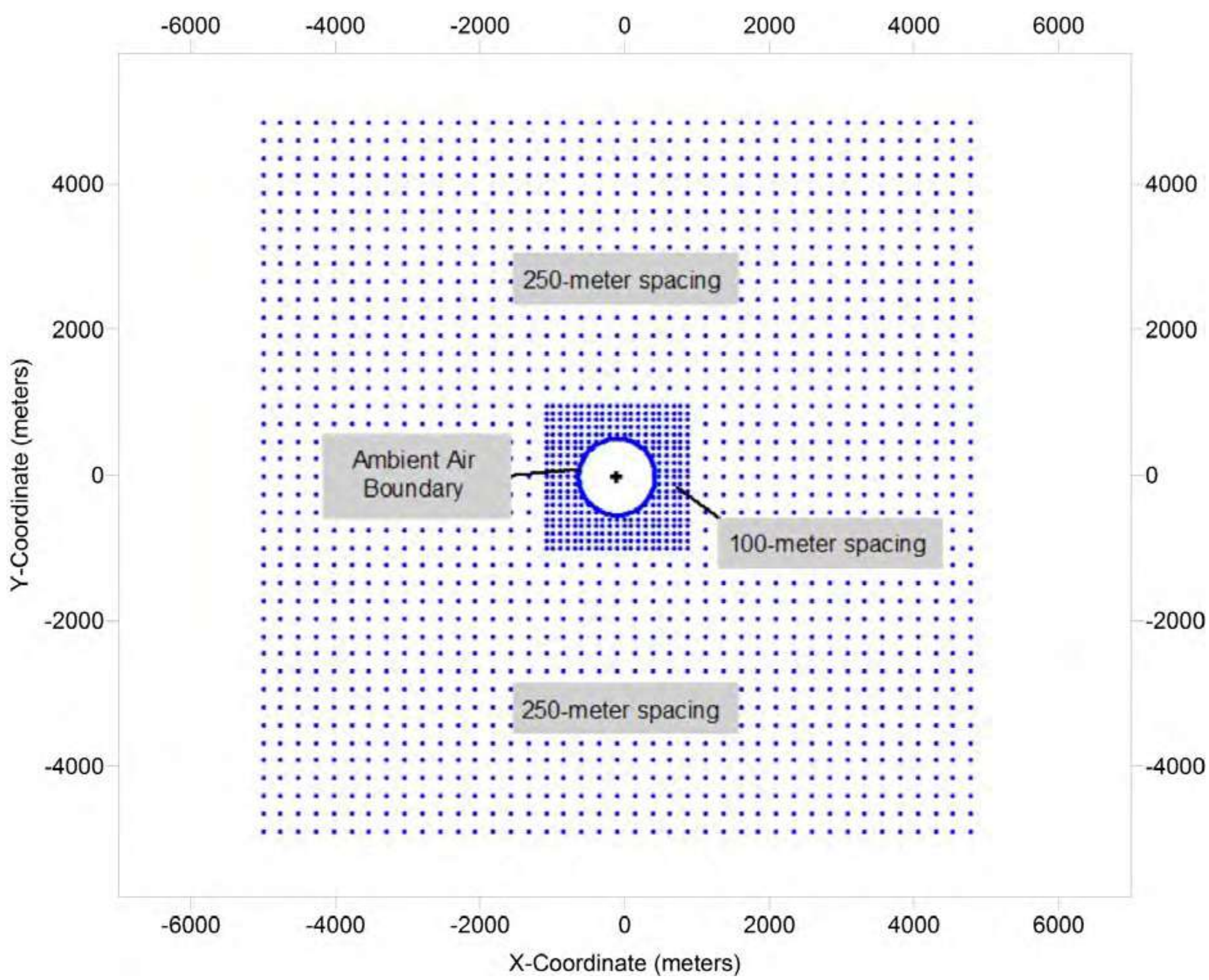
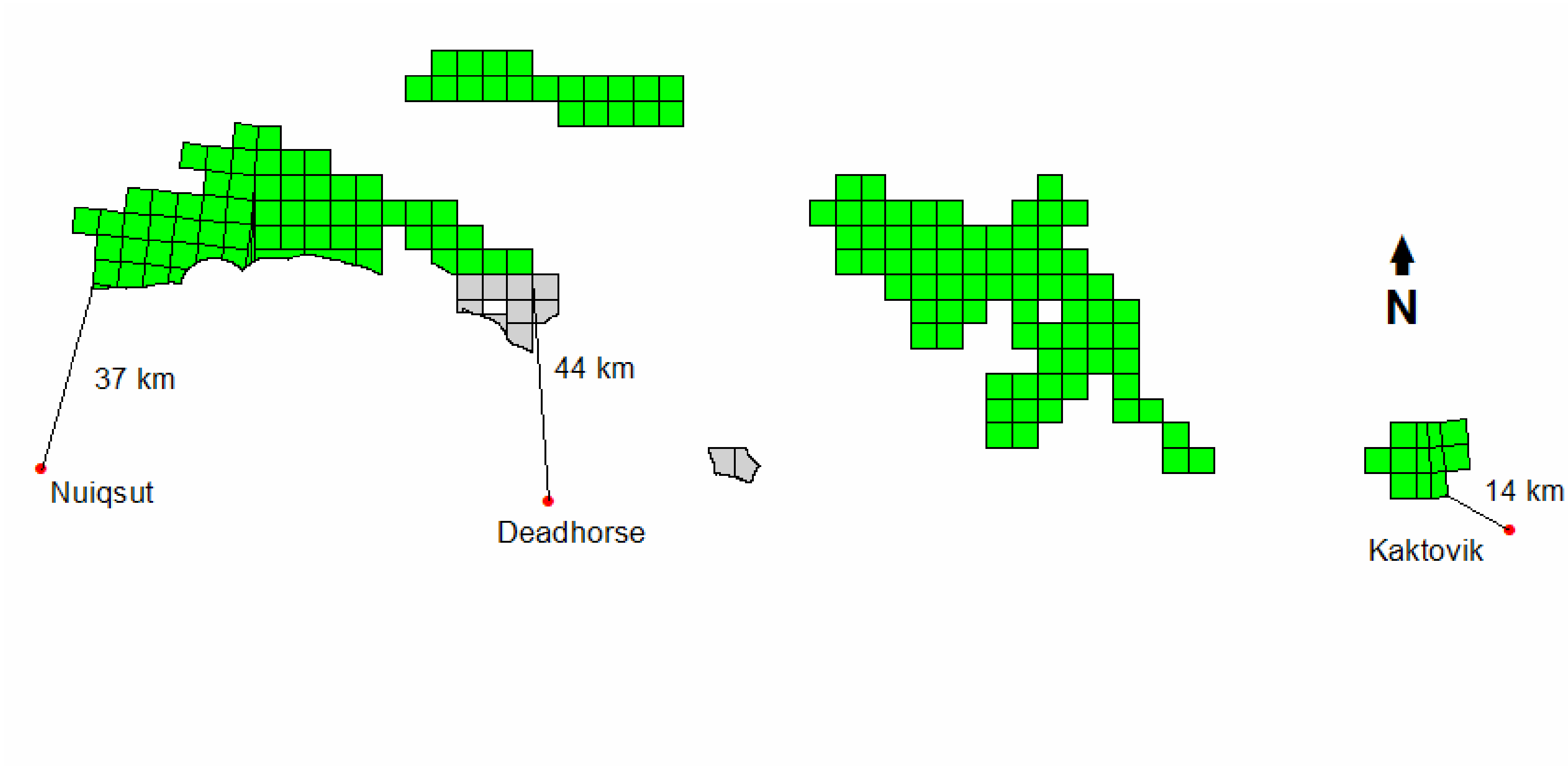


Figure 4: Map of Nearest Communities on the Beaufort Coast Relative to the Kulluk OCS Leases

Note: Shell dropped the gray-shaded lease blocks from permitting consideration in the Kulluk application.



D.11 Offsite Impacts

The impact from neighboring (off-site) sources must be accounted for in a cumulative impact assessment. Per Section 8.2.3 of Appendix W, "all sources expected to cause a significant concentration gradient in the vicinity of the [applicant's source] should be explicitly modeled." The impact from other sources can be accounted for through ambient monitoring data.

Shell did not address potential off-site impacts in their February 2011 permit application. Region 10 therefore asked Shell to address this modeling deficiency in our March 18, 2011 incompleteness letter.

A common long-term practice for selecting the "nearby" sources for explicit modeling was to follow a very prescriptive procedure in EPA's draft New Source Review Workshop Manual (Manual) (EPA 10/90). Under this approach, an off-site source located within the applicant's "significant impact area" (SIA) would need to be explicitly modeled. Sources located beyond the applicant's SIA, but with impacts inside of the SIA, would also be candidates for modeling.

EPA recently clarified that "following such procedures in a literal and uncritical manner may in many cases result in cumulative impact assessments that are overly conservative" (EPA 03/11). Appendix W is consistent with this approach, stating that professional judgment is required for ascertaining which sources should be explicitly modeled and which sources can be represented through ambient monitoring data.

Shell and Region 10 discussed the possible options for assessing off-site impacts in an April 7, 2011 teleconference. Region 10 subsequently provided general guidance for Shell's consideration (EPA 4/14/11). Region 10 specifically noted that Shell may be able to limit the modeling of nearby sources by switching to ambient data that better accounts for the impacts from off-site sources.

Attachment B of Shell's May 4, 2011 submittal successfully showed that the impact from off-site sources could be accounted for through ambient monitoring data rather than modeling (Shell 05/04/11). The maximum project impacts occur near the Kulluk. Region 10 notes that this is a typical finding for sources with relatively short stacks and plumes subject to downwash. Additional information regarding the ambient data used to represent the off-site/background concentrations may be found in Section F of this TSD.

Shell did not include the Discoverer drilling program in their Kulluk analysis since they have agreed to not operate the Discoverer in the Beaufort Sea concurrently with the Kulluk. Although there are currently no other permitted exploratory drilling operations in the OCS north of Alaska, Region 10 is aware of additional permit applications for operations that could potentially be in the Beaufort Sea. Region 10 intends to require all permitted operations to notify Region 10 regarding their anticipated drilling locations far in advance of each drilling season (6 months) so that Region 10 can evaluate whether there is a need for additional ambient analyses.

E. Meteorological Data/Processing

AERMOD requires hourly surface meteorological data to estimate plume dispersion. According to Appendix W, a minimum of one-year of site-specific data, or five years of representative National Weather Service (NWS) data should be used. When modeling with site-specific data, Appendix W states that additional years (up to five) should be used when available to account for year-to-year variation in meteorological conditions. AERMOD also requires a morning sounding from a representative upper air station.

Shell used July through November meteorological data from 2009 and 2010 for modeling most pollutants. The one exception regards the NO_2 analysis. In this case, Shell was unable to use the 2010 meteorological data since concurrent ozone data was not available at the time of the analysis (see NO_2 modeling discussion in Section D.7 of this TSD). Additional information regarding the meteorological data sets and Shell's processing of these data sets may be found below.

E.1 Meteorological Data Sets

Because the drilling season spans periods of both open water and ice, Shell needed several different meteorological data sets. Shell collected tower (surface) data at a small offshore island (Reindeer Island) during 2009 and 2010. The measured parameters included 10-meter wind speed/direction, air temperature, differential temperature between 10-meters and 2-meters, solar radiation, and pressure. Shell assumed the wind data adequately reflects marine boundary layer conditions without undue influence from the island since the island is small, there is little terrain relief, and the tower was located very close to the edge of the narrow island. Region 10 agrees with Shell's assessment of this location and considers the Reindeer Island data as site-specific for the Kulluk ambient impact assessment. Shell used concurrent upper air data from the nearest available source, the NWS station in Barrow, Alaska.

Region 10 reviewed the Reindeer Island meteorological data and determined that it meets the PSD quality assurance requirements. Shell filled in missing Reindeer Island data with Deadhorse NWS data.

In addition to the Reindeer Island surface data, Shell needed air-sea temperature difference data and overwater relative humidity data to run the COARE meteorological program during open water conditions. Shell deployed instrumented buoys during the open water periods in 2009 and 2010 to obtain the air-sea temperature and humidity data.

COARE provides most of the meteorological inputs required by AERMOD. However, COARE does not provide mixing height data. Shell therefore operated a thermal profiler at Endeavor Island (Endicott) during 2010 to develop the overwater mixing heights. Shell developed an empirical equation from the profiler data to derive the mixing heights during the open water periods in 2009 (when actual profiler data were not available). Additional details regarding Shell's processing of the meteorological data may be found in Appendix B and C of their permit application.

Region 10 reviewed the profiler data, the quality assurance audits, high-resolution radiosonde data, temperature and potential temperature profiles, and other calculated parameters associated with the COARE dataset. Diagnosed mixing heights using the Richardson number along with imposed restrictions on mixing heights were also reviewed by Region 10 and found to be representative for use in the Kulluk analysis.

E.2 Meteorological Pre-Processing

The meteorological data must be processed into a format that AERMOD recognizes. As previously discussed, Shell used two different meteorological pre-processors: one to process the meteorological data during broken ice conditions (AERMET), and the other to process the meteorological data during open water conditions (COARE). Shell defined the open water period as the time a buoy could be deployed (August 5 – October 13, 2009; and August 14 – October 10, 2010).[5]

E.2.1 COARE

As previously noted, COARE is a non-Guideline model. Use of this model therefore requires Regional Office approval. It is also subject to public comment. The Regional Modeling Contact for Region 10 approved Shell's use of COARE for the Kulluk analysis on May 8, 2011 (EPA 05/08/11). The public will also be invited to comment on the use of COARE in the public notice which will accompany the draft permit.

E.2.2 AERMET

Shell used the current version of AERMET (06341) at the time of the February 28, 2011 submittal. EPA has subsequently released a newer version (11059), but this release does not alter the validity of Shell's submittal.[6]

AERMET requires the area surrounding the meteorological tower be characterized in regards to the following three surface characteristics: noon-time albedo, Bowen ratio, and surface roughness length (EPA 11/04 AERMET). Additional guidance regarding the selection and processing of these values may be found in the *AERMOD Implementation Guide* (EPA 03/19/09).

Shell assumed the noon-time albedo is 0.8, the Bowen ratio is 2.0 and the surface roughness length is 0.001. These values are identical to the values previously approved by ADEC for winter conditions (i.e., ice conditions) on the Beaufort Sea (ADEC 2007).

F. Background Air Quality Data

Background monitoring data is used in conjunction with modeled predictions to determine if the combined impact complies with the NAAQS. The data should represent impacts from sources not specifically modeled; such as natural, area-wide, long-range transport and distant stationary sources.

[5] Once deployed, Shell left the buoys in the Beaufort Sea until they were destroyed by the pack-ice.
[6] The primary reason for EPA's recent release of a new version of AERMET is to provide applicants the ability to derive wind information from 1-minute, rather than hourly, NWS data. The use of 1-minute NWS data is not required, though, and this additional algorithm is non-applicable when using site-specific meteorological data.

Because there are no islands, platforms, or infrastructure in the Beaufort Sea in the vicinity of Shell's offshore operations on which to install, operate, and maintain ambient air quality monitoring equipment, it is appropriate to use onshore preconstruction monitoring data as a conservative representation of background concentrations in the vicinity of Shell's operations. The onshore data is expected to be conservative because these onshore monitoring stations will be influenced by local sources that are not present in the vicinity of Shell's offshore operations.

Shell used ambient data collected at a number of on-shore monitoring stations for their background concentrations. They originally used the 2009 monitoring data that they collected near Badami for the background NO_2 and PM-2.5 concentrations. They later switched to data collected from the greater Prudhoe Bay area to better account for possible impacts from existing sources. The location of each background data set proposed by Shell is summarized below in Table 8.

Table 8: Location of Background Data Used by Shell

Air Pollutant	Data Location	Data Period
NO_2	Prudhoe Bay A Pad	2006, 2007, 2009
PM-2.5	Deadhorse	July 2010 – Nov 2010
PM-10	Prudhoe Bay CCP [a]	2006, 2007
SO_2	Endicott SDI [b]	July 2007 – Nov 2007 for short-term averages, Feb 2007 – Jan 2008 for annual average
CO	Endicott SDI [b]	Endicott (July 2007 – Nov 2007

[a] Shell identified the PM-10 data as "BPX Prudhoe Bay area." BPXA operates two ambient air monitoring stations within Prudhoe Bay. However, BPXA only collects PM-10 data at the "Central Compressor Plant" (CCP) site.
[b] Shell identified the SO_2 and CO data as "BPXA Liberty." This title actually refers to a project. BPXA collected the "Liberty" data set at the Endicott Satellite Development Island (SDI).

Region 10 considered the datasets presented by Shell and then conducted an independent evaluation of the available monitoring data to determine which datasets Region 10 believes are most representative of background values. Region 10 made this determination for both the offshore locations near the Shell lease blocks, as well as at the onshore communities where the air quality impact from the Kulluk and associated fleet is being evaluated. Region 10's findings are described in a June 23, 2011 memorandum, "EPA Region 10 Determination of Appropriate Background Values for the Chukchi Sea and Beaufort Sea OCS Permits." Table 9 summarizes the monitoring sites and the background values that Region 10 believes best represent offshore locations in the Beaufort Sea.[7] Each of the data sets used for the Kulluk offshore locations are discussed in more detail below.

[7] Table 6 of Region 10's June 23, 2011 memorandum incorrectly highlighted the CCP value for the annual average NO_2 concentration at offshore locations (19 $\mu g/m^3$). Region 10 intended to highlight the A Pad value (11 $\mu g/m^3$). While Shell can demonstrate compliance with the annual average NO_2 NAAQS using either value, Region 10 considers the CCP value to be an overly conservative estimate of the expected background concentration at the offshore lease blocks. Region 10 therefore used the A Pad value in this TSD.

Table 9: Background Values for Use with Modeled Impacts at Offshore Locations

Air Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Data Source
NO_2	1-hour	Varies by hour	A Pad
	Annual	11	
PM-2.5	24-hour	17	Deadhorse
	Annual	4	
PM-10	24-hour	53	CCP
SO_2	1-hour	29	CCP
	3-hour	29	
	24-hour	22	
	Annual	4	
CO	1-hour	1,742	SDI
	8-hour	1,094	

Table 10 summarizes the monitoring sites and background values that Region 10 believes are appropriate for evaluating impacts in the Kaktovik and Nuiqsut onshore communities. Region 10 used the offshore values presented in Table 9 to represent the background concentrations in Deadhorse.

Table 10: Background Values for Use with Modeled Impacts at Onshore Locations

Air Pollutant	Averaging Period	Katkovik		Nuiqsut	
		Concentration ($\mu g/m^3$)	Data Source	Concentration ($\mu g/m^3$)	Data Source
NO_2	1-hour	21	Badami	94	A Pad
	Annual	1		11	
PM-2.5	24-hour	6	Badami	17	DeadHorse
	Annual	3		4	
PM-10	24-hour	53	CCP	53	CCP
SO_2	1-hour	10	SDI	14	A Pad
	3-hour	11		180	
	24-hour	4		25	
	Annual	2		4	
CO	1-hour	1,742	SDI	1,742	SDI
	8-hour	1,094		1,094	

While ambient data is currently being collected in Nuiqsut, Region 10 instead used ambient data from Prudhoe Bay to represent the background values in Nuiqsut. Region 10 took this approach since the Nuiqsut data has not been submitted to Region 10 for review. The Prudhoe Bay data should also provide a more conservative estimate of the background values due to the close proximity of these monitoring stations to the oil and gas sources in Prudhoe Bay. Where available, Region 10 has used data from sites west of Prudhoe Bay for Nuiqsut and sites to the east of Prudhoe Bay for Katktovik, with a preference for more recent data if more than one site has data for the same pollutant. As discussed above, the only reviewed PM-10 data is from the CCP site and so that data set was used for both Nuiqsut and Kaktovik. From the available data, Region 10 calculated background values following the provisions of the applicable appendices to 40 CFR Part 50 and EPA modeling guidance.

F.1 A Pad NO_2 Data

As previously noted, Shell switched from Badami data to Prudhoe Bay A Pad data to represent the NO_2 background concentrations at their offshore locations. As discussed in Section D.11, Region 10 agrees that this switch better accounts for the possible impacts from on-shore sources.

There are three years of recent PSD-quality NO_2 data available from A Pad (2006, 2007 and 2009). The 2008 NO_2 data is not PSD-quality, and therefore, should not be used for regulatory purposes (Enviroplan 2010a). The NO_2 data from the other years was reviewed by ADEC, who found them to be PSD-quality (ADEC 2008, ADEC 2009, Enviroplan 2010b). Shell used the maximum annual average NO_2 concentration between the three years of available data to represent the annual average NO_2 background concentration. The use of the maximum concentration is appropriate.

The 1-hour NO_2 NAAQS is based on an annual distribution of the daily maximum 1-hour value. Due to the probabilistic nature of this standard, applicants may use the monitored design value to represent the background concentration, rather than the maximum measured concentration (EPA 03/01/11). They may also use hourly values that represent the seasonal diurnal pattern of the ambient concentrations. In this case, applicants may add the multi-year average of the 98^{th} percentile of the available background concentrations by season and hour-of-day to the modeled concentration. In rare cases, the use of additional refinements, such as combining the background and modeled concentrations on an hour-by-hour basis may be warranted.

Shell originally paired the hourly background concentration and hourly modeled concentration on an hour-by-hour and day-by-day basis. Region 10 felt this approach was not adequately robust for purposes of this ambient demonstration, and instead asked Shell to use hourly background concentrations that reflect the diurnal profile of the NO_2 concentrations measured during the July through November drilling season.

Shell calculated a diurnal NO_2 profile based on a three-year average of the NO_2 concentrations measured in 2006, 2007 and 2009. They then combined the modeled concentrations with the background concentration on an hour-of-day basis to determine the total impact. The 98^{th} percentile of the maximum daily 1-hour total impact was then compared to the 1-hour NO_2 NAAQS.

F.2 CCP PM-10 and SO_2 Data

As with the NO_2 data, PM-10 and SO_2 data from the Prudhoe Bay area is warranted in order to best represent the possible impact from onshore sources at the offshore locations. The only PM-10 data set within Prudhoe is from the CCP. This is a conservative data set due to its close proximity (on the order of 100 meters) to two large Prudhoe Bay stationary sources: the Central Power Plant and Central Gas Facility.

There are three SO_2 data sets from the greater Prudhoe Bay area (CCP, A Pad and SDI). Shell used data from the SDI station in their application. Region 10 felt that either A Pad or CCP data was a better selection for representing potential impacts from onshore sources since these stations are located downwind of CCP and CGF. Of these data sets, the CCP set would typically provide the more conservative result due to its closer proximity to these stationary sources. The A Pad data sets also contained two anomalously high hourly values (336 $\mu g/m^3$ and 202 $\mu g/m^3$) that were an order of magnitude larger than the next highest value (20 $\mu g/m^3$). While Region 10 could have processed the A Pad data to determine a 1-hour SO_2 background concentration in the form of the 1-hour SO_2 standard, Region 10 instead took the simpler and more conservative approach of using the maximum value from CCP (29 $\mu g/m^3$). Region 10 also used the CCP data for the other SO_2 averaging periods for consistency purposes.

F.3 Deadhorse PM-2.5 Data

As previously noted, Shell originally used data measured near Badami to represent the expected PM-2.5 background concentration at their offshore locations. They latter switched data sets in order to better account for the potential impacts from existing onshore sources.

There are only two other complete PM-2.5 data sets from monitoring stations located along the Beaufort Sea: a data set from Nuiqsut and a data set from Deadhorse.[8] The Nuiqsut station was sited to measure regional impacts from the Kuparuk River Unit oilfield. The Deadhorse station (which is near Prudhoe Bay) only has data from 2010. The station was sited near gravel roads and pads in order to measure elevated concentrations for purposes of comparing the results between "Federal Reference Method" equipment and "Federal Equivalent Method" equipment.[9] While the Deadhorse data includes elevated fugitive dust impacts from the gravel roads and pads, it is nevertheless the more conservative data set for measuring impacts from existing North Slope stationary sources.

Shell used the Deadhorse data to represent the background PM-2.5 concentration within the Kulluk lease blocks. This is an acceptable data set due to its inclusion of both direct PM-2.5 emissions and potential secondary PM-2.5 impacts, as previously discussed in Section D.8 of this TSD. Region 10 reviewed the latest PM-2.5 monitoring data to ensure that the background values used in the ambient air analysis are representative of background values and to ensure the data being used followed the latest EPA modeling guidance. (EPA 06/23/11).

F.4 SDI CO Data

CO is not routinely measured within Prudhoe Bay due to its low ambient concentration in this region. The most recent data set was collected by BPXA at SDI. Shell and Region 10 used this data set to represent the background CO concentrations at both offshore and onshore locations.

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[8] BP Exploration Alaska, Inc. (BPXA) has recently started collecting PM-2.5 data at their CCP monitoring station in Prudhoe Bay, but the dataset does not yet cover Shell's July through November exploratory drilling period.

[9] The Deadhorse station is located closer to a road than recommended in EPA's PSD monitoring guidance (CPAI 2009), and therefore, measures concentrations that are higher than what would typically be found. It was purposely placed at this worst-case location to counter the typical low PM-2.5 concentrations measured on the North Slope. Placement at this location allowed for higher concentrations to be measured, which was needed in order to accurately compare the two monitoring methods.

G. Results and Discussion

The maximum modeled NO_2, SO_2, PM-10, PM-2.5, and CO impacts, background concentrations, total impacts, and NAAQS are summarized below in Table 11. All of the total impacts are less than the NAAQS. The modeling results show that the emissions associated with the proposed permit are not expected to cause or contribute to a violation of the NAAQS. The maximum 8-hour NH_3 impact is 6.6 μg/m^3 which is well below the State of Alaska air quality standard of 2,100 μg/m^3.

Table 11: Modeled Impacts at the Location of Maximum Impact

Air Pollutant	Averaging Period	Shell Only Impacts (without background) (μg/m^3)	Background Concentration (μg/m^3)	Total Impact Including Background (μg/m^3)	NAAQS (μg/m^3)	Total Impact as a % of NAAQS
NO_2	1-hour	110.6	40.9	**151.5**	188	81%
	Annual	4.4	11	**15.4**	100	15%
PM-2.5	24-hour	17.0	17	**34.0**	35	97%
	Annual	1.0	4	**5.0**	15	33%
PM-10	24-hour	20.8	53	**73.8**	150	49%
SO_2	1-hour	14.0	29	**43.0**	196	22%
	3-hour	8.9	29	**37.9**	1,300	3%
	24-hour	2.8	22	**24.8**	365	7%
	Annual	0.2	4	**4.2**	80	5%
CO	1-hour	1,268	1,742	**3,010**	40,000	8%
	8-hour	712	1,094	**1,806**	10,000	18%

H. Ozone

This section provides additional information regarding ozone and why Region 10 believes it is appropriate not to require a quantitative assessment that includes modeling for this pollutant. Ozone is inherently a regional pollutant, the result of chemical reactions between emissions from many sources over a period of hours or days, and over a large area. Ozone is formed in the atmosphere through a chemical reaction that includes NOx, VOC, and CO in the presence of sunlight. The sources of these air pollutants are mainly combustion sources such as power plants, refineries, and automobiles.

EPA does not have a recommended modeling approach for assessing the impact of an individual source on ozone. Individual source impacts are generally within the range of "noise" of regional ozone models (i.e., imprecision in predicted concentration due to uncertainty in model inputs for emissions, chemistry, and meteorology). Section 5.2.1(a) of Appendix W reflects this understanding: "Simulation of ozone formation and transport is a highly complex and resource intensive exercise." Paragraph (c) states: "Choice of methods used to assess the impact of an individual source depends on the nature of the source and its emissions. Thus, model users should consult with the Regional Office to determine the most suitable approach on a case-by-case basis." Under the Appendix W, Region 10 has considerable discretion in methods for assessing the ozone impact of individual sources. See In re: Prairie State Generating Company, 13 E.A.D. 1, PSD Appeal No. 05-05, slip op. at 133 (EAB 2006). In practice, it is very rare for EPA to require ozone modeling for individual sources.

The land area closest to Shell's exploration operations is part of the State of Alaska's Northern Alaska Intrastate Air Quality Control Region. See 40 CFR § 81.246. This region is designated as either attainment or unclassifiable for all criteria pollutants, including ozone. See 40 CFR § 81.301. Ozone precursor emissions from point sources in the North Slope oil and gas fields near Deadhorse contribute approximately 65,000 tpy of NOx and 1,100 tpy of VOC. Even so, the 8-hour ozone design concentration measured within Prudhoe Bay (A Pad) is 34 ppb, which is less than the 75 ppb NAAQS (EPA 06/23/11). Since the allowable NOx and VOC emissions from the Kulluk and associated fleet only a small fraction of this total amount (240 tpy of NOx and 40 tpy of VOC) and will occur away from the existing emissions, it is unlikely that this small increase in ozone precursor emissions would cause or contribute to a violation of the ozone NAAQS.

I. On Shore Impacts

Maximum impacts from the Kulluk's emissions are at the assumed ambient air boundary (500 meters from the Kulluk hull) and decline rapidly as the distance from the drill rig increases. The maximum predicted impacts in the local communities of Nuiqsut, Deadhorse and Kaktovik, which are respectively located approximately 37, 44, and 14 km from the closest leaseblocks, are shown in Table 12. The significant impact level (SIL) established under the PSD program is also shown.

As discussed above, although the PSD requirements for NAAQS demonstrations are not applicable to this analysis, they do serve as a useful guide. EPA has established Significant Impact Levels or SILs under the PSD program to characterize air quality impacts from sources that undergo PSD review. A SIL is a threshold level for the ambient concentration resulting from a source's emissions for a given pollutant and averaging period below which the source is considered too small to cause or contribute to a violation of the NAAQS.

As shown in Table 12, the Kulluk impacts are well below the SILs in all three communities. In many cases, the impacts are smaller by an order of magnitude or more. EPA is nevertheless providing the total impacts (Shell plus background) for comparison to the NAAQS in Table 13.

Table 12: Maximum Modeled Impacts at Nearest Communities (from Kulluk operations, excluding background concentrations)

Air Pollutant	Averaging Period	Kulluk Impacts ($\mu g/m^3$) at			SIL ($\mu g/m^3$)
		Nuiqsut	Deadhorse	Kaktovik	
NO_2	1-hour	0.04	0.02	0.3	**8**
	Annual	0.03	0.02	0.1	**1**
PM-2.5	24-hour	0.2	0.1	0.5	**1.2**
	Annual	0.004	0.004	0.01	**0.3**
PM-10	24-hour	0.3	0.2	0.5	**5**
SO_2	1-hour	0.4	0.5	0.7	**8**
	3-hour	0.2	0.2	0.3	**25**
	24-hour	0.05	0.03	0.1	**5**
	Annual	0.001	0.001	0.002	**1**
CO	1-hour	201	182	333	**2,000**
	8-hour	117	105	180	**500**

Table 13: Total Impacts at Nearest Communities (from Kulluk operations and including background concentrations)

Air Pollutant	Averaging Period	Total Impacts ($\mu g/m^3$) at			NAAQS ($\mu g/m^3$)
		Nuiqsut	Deadhorse	Kaktovik	
NO_2	1-hour	94	94	21	**188**
	Annual	11	11	1	**100**
PM-2.5	24-hour	17	17	7	**35**
	Annual	4	4	3	**15**
PM-10	24-hour	53	53	53	**150**
SO_2	1-hour	14	29	10	**196**
	3-hour	180	29	11	**1,300**
	24-hour	25	22	4	**365**
	Annual	4	4	2	**80**
CO	1-hour	1,943	1,924	2,075	**40,000**
	8-hour	1,211	1,199	1,274	**10,000**

J. Conclusions

Region 10 has reviewed and determined that the materials, air quality data, meteorological measurements, and model input and output files submitted by Shell satisfy the requirements in Appendix W to make adequate demonstration of compliance with the NAAQS. The AERMOD and AERMOD-COARE modeling predicted concentrations with representative background concentrations do not show a violation of any NAAQS. Shell has used the worst case emissions and has used worst case vessel emissions when more than one candidate vessel is available.

Movement of the drilling ship will decrease short-term impacts of all pollutants, especially in the near field where high modeled concentrations occur, if averaging were performed over multiple years. The assumption of a fixed drilling location for the entire 120 day OCS period produces a conservative analysis (i.e., the predicted modeled impacts are larger than what would likely be realized with a moving ship with averaging over a longer period of time).

Finally, modeled impacts generally decrease as the distance from the 500 meter assumed ambient air boundary increases, and on average there is a rapid decrease in concentrations as the distance from the Kulluk increases. Modeled impacts at all on-shore locations are well below the NAAQS.

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